Research Article

Functional outcomes in patients with co-occurring traumatic brain injury and spinal cord injury from an inpatient rehabilitation facility's perspective

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Objective: To examine the occurrence and severity of co-occurring traumatic brain injury (TBI) in persons with traumatic spinal cord injury (SCI), i.e. dual diagnosis (DD), and to describe differences in functional outcomes between persons with DD and SCI only from an inpatient rehabilitation facility (IRF) perspective.
Design: Retrospective clinical chart review.
Setting: Acute Midwest SCI inpatient rehabilitation facility.
Participants: 256 persons age 18-80 years with acute traumatic SCI (AIS A-E, C1-S3 level of injury) from 2002-2012.
Interventions: Neuroimaging and electronic medical records were reviewed to identify those with co-occurring TBI. Outcomes were then compared between the SCI only and DD groups.
Outcome Measures: Length of stay (LOS), discharge location and functional independence measures (FIM)
Results: Forty-one percent of persons with traumatic SCI experienced co-occurring TBI. Rehabilitation LOS for the DD groups did not differ significantly from the SCI only group. Those with Moderate-Severe DD had significantly lower Total admission FIM ($P < 0.001$), Cognitive admission and discharge FIM (both $P < 0.001$) and Motor FIM efficiency scores ($P = 0.03$) compared to those with SCI only and were significantly less likely to discharge home ($P = 0.05$).
Conclusions: Persons admitted to IRFs with Moderate-Severe DD compared to those with SCI only are less efficient in obtaining motor skills and may require ongoing rehabilitation to safely return home. It is therefore imperative to initiate early discharge planning and educate rehabilitation team members and families on the additional time and resources necessary to achieve more successful outcomes in those with Moderate-Severe DD.

Keywords: Spinal cord injury, Traumatic brain injury, Dual diagnosis, Functional outcomes, Cord injury rehabilitation

Introduction

Successful rehabilitation of persons with spinal cord injury (SCI) requires the ability to learn new skills, retain information, and problem solve. Clinicians working with persons with SCI have long known that these important skills can be impaired with co-occurring traumatic brain injury (TBI), more commonly referred to as dual diagnosis (DD). Early research studies attempted to determine the occurrence of DD. An assortment of diagnostic criteria were used and differed among the various studies, including ICD-9 codes, loss of consciousness (LOC), post traumatic amnesia (PTA), Glasgow Coma Scale (GCS), positive neuroimaging and neuropsychologic testing. The reported occurrence ranged from 16-59% based on stringency of criteria.[1–7] In a more recent prospective study, Macciocchi *et al.*[8] in 2008 created a diagnostic algorithm using presence and duration of PTA, initial GCS and neuroimaging to determine the occurrence and severity of TBI in their SCI sample. Nearly 60% of persons with SCI had co-occurring TBI in this study, most of mild severity. However, there is no universally accepted classification system for TBI severity. This

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contributes to the difficulty in comparing reported DD incidence, TBI nosology, and in turn the functional outcomes among these studies.

Rehabilitation outcomes of persons with DD have scarcely been reported in the current literature. The majority of recent studies are generated from long term acute care (LTAC) facilities or facilities outside of the United States.[9–12] Two case-matched studies compared functional outcomes in those with SCI only versus those with DD. In the first study, performed in a United States LTAC facility, individuals were matched by SCI level and admission motor Functional Independence Measure (FIM) scores. Those with DD were shown to have more impaired cognitive FIM scores at admission and discharge and lower motor FIM change despite having the same mean rehabilitation length of stay (LOS, 43 days) and a longer acute care stay than those with SCI alone (24 days vs. 12 days respectively).[9] However, the second study performed in a Canadian inpatient rehabilitation hospital demonstrated comparable FIM scores between the DD group and SCI only group when individuals were matched by SCI level, completeness of injury, sex, age and years of education.[12] Acute care LOS (55 days vs. 33 days) and rehabilitation LOS (138 days vs. 100 days) was longer for those with DD but did not reach significant differences. The differing functional outcomes in the previous studies are most likely related to differences in the acute and rehabilitation LOSs. The results of these studies are difficult to translate to SCI practice in United States inpatient rehabilitation facilities (IRFs), as inpatient rehabilitation LOS at IRFs are significantly shorter and have continued to decline in the past decade.[13–14] This demonstrates an additional cause of difficulty in comparing functional outcomes across facilities depending on the type and location or payment system of the facility.

In order to provide specialized care, it is imperative to identify and understand the differences in functional outcomes of those with DD versus those with SCI only. This information will assist healthcare providers, caregivers and other stakeholders regarding the delivery of comprehensive treatment plans including cognitive rehabilitation services. Adaptations to the typical rehabilitation plan within an IRF such as additional rehabilitation days may be necessary in order for these patients to discharge home and return to the community. The current study is unique in that the data set consists of individuals that have undergone inpatient rehabilitation at an acute IRF located in the rural Midwest where rehabilitation LOS is considerably shorter compared to non-US and LTAC facilities described above. This study also used an inclusive system designed for retrospective research to classify TBI severity via the Mayo Classification System.[15] The specific aims of this study were to 1) determine the occurrence and severity of TBI in persons sustaining a co-occurring traumatic SCI admitted to an acute IRF and 2) compare outcomes between persons with Mild DD to SCI only and Moderate-Severe DD to SCI only using the (Cognitive, Motor and Total) FIM scores at rehabilitation hospital admission and discharge, FIM efficiency, rehabilitation LOS and discharge location. Based on existing research, we hypothesized that if LOS was not significantly different between SCI only and DD groups, then the short term functional outcomes including Cognitive and Motor FIM scores at discharge and corresponding efficiency scores would be significantly lower in the DD groups, and that discharge locations would differ (home vs. facility). The goal was to add to the existing DD literature from an IRF perspective to better anticipate patients' needs during and following IRF admission, individualize treatment plans and prognosticate and advocate effectively with payers and employers.

Methods

Participants

Initial retrospective chart review collected 331 admissions of persons with traumatic SCI (AIS A-E, C1-S3 level of injury) between the years 2002 to 2012 using the Uniform Data System (UDS) for Medical Rehabilitation Software. Persons admitted to the acute IRF were between the ages of 18 and 80 years at time of injury. Completeness of injury was classified via the American Spinal Injury Association (ASIA) Impairment Scale (AIS), in which "A" represents complete motor and sensory injury, and "B through E" represents incomplete injuries.[16,17] Ten people were excluded from the analysis as their onset days (time elapsed between inpatient rehabilitation date and etiologic date) exceeded six months post injury.

Sixty-five people had multiple rehabilitation admission entries within our database, which were consolidated into one rehabilitation stay per person. If the person was discharged home and returned for a subsequent rehabilitation phase, only the initial rehabilitation stay data was analyzed, whereas if the person was transferred off floor, the primary rehabilitation admission information and final discharge information was combined to calculate one set of functional outcome data (FIM scores).[18–20] For the latter cases, the LOS was re-calculated by summing the days spent on the rehabilitation unit from each inpatient rehabilitation admission. Transfer days off floor were excluded from total rehabilitation LOS as this method would provide the most accurate FIM efficiency scores during data analysis.[20] The total number of persons analyzed for this retrospective review was 256 patients.

Procedure

Acute care medical records, neuroimaging, neuropsychology notes and rehabilitation notes were retrospectively reviewed for positive neuroimaging findings or documentation of LOC, PTA or GCS of 13 or less on acute hospital admission to identify those with co-occurring acute TBI. TBI classification was made on the basis of the Mayo Classification System for Traumatic Brain Injury Severity scale (Table 1).[15] 'Mild' and 'Moderate-Severe' TBI severity classifications were used in this study while excluding the 'Symptomatic' classification. The persons whom fell under the 'Symptomatic' TBI classification (n = 10) were combined with the SCI only group for analysis as the 'Symptomatic' classification is based off subjective symptoms that could potentially be related to chronic conditions such as pain, depression and anxiety disorders or be influenced by confounding issues such as alcohol consumption, medication side effects, intensive care unit environment, etc. Those with 'Symptomatic' classification did not have symptoms specific to TBI nor positive evidence of TBI, therefore they were considered more clinically similar to the SCI only group. A 'Mild' classification of TBI was considered one in which the individual had LOC for less than 30 minutes, GCS score of 13/15 within 30 minutes of injury or PTA that did not extend beyond 24 hours. If the time frames were exceeded, or evidence of trauma related abnormalities was revealed on neuroimaging, the TBI was classified within the Moderate-Severe range. To further validate whether or not TBI was present and the correct severity classification was given, two board certified TBI physiatrists performed a blind chart review of all 256 subjects. Differences in classifications were reconciled via consensus vote from both the primary investigators and TBI physiatrists after reviewing the electronic medical record again as a group.

Table 1 Mayo TBI Severity Classification System.

TBI Severity	Criteria
A. Definite (Moderate/Severe)	A. If 1 or more of the following criteria apply: 1. Death due to this TBI 2. Loss of consciousness of ≥30 minutes 3. Posttraumatic anterograde amnesia of ≥24 hours 4. Worst Glasgow Coma Scale full score <13 in first 24 hours (unless invalidated upon review, e.g. attributable to intoxication, sedation, systemic shock) 5. One or more of the following present: • Intracerebral hematoma • Subdural hematoma • Epidural hematoma • Cerebral contusion • Hemorrhagic contusion • Penetrating TBI (dura penetrated) • Subarachnoid hemorrhage
B. Probably (Mild)	B. If none of criteria A apply, and 1 or more of the following criteria apply: 1. Loss of consciousness that is momentary or lasts <30 minutes 2. Posttraumatic anterograde amnesia that is momentary or lasts <24 hours 3. Depressed, basilar or linear skull fracture (dura intact)
C. Possible (Symptomatic)	C. If none of criteria A or B apply, and 1 or more of the following symptoms are present: • Blurred vision • Confusion (mental-state changes) • Dazed • Dizziness • Focal neurologic symptoms • Headache • Nausea

Outcome measures collected included (Cognitive, Motor and Total) FIM scores at rehabilitation hospital admission and discharge, FIM efficiency ((Discharge FIM minus Admission FIM) divided by rehabilitation LOS), rehabilitation LOS and discharge location. FIM assessments were completed at admission to rehabilitation (within 72 hours) and within 24 hours of discharge by UDS certified rehabilitation specialists, thus ensuring inter-rater reliability.

Data analysis

Descriptive statistics were calculated for the total cohort and three subgroups defined by severity of TBI; no or symptomatic TBI (SCI only), Mild TBI + SCI (Mild DD) and Moderate-Severe TBI + SCI (Moderate-Severe DD). Significant inter-group differences were assessed with the chi[2] text for categorical variable and analysis of variance for continuous variables. Skew and kurtosis testing was performed for all dependent variables. Ordinary least squares regression models were used to estimate the association of group with admission and discharge FIM scores, as well as FIM efficiencies for Total, Cognitive and Motor subscale scores. To adjust for potential confounding; age at injury, level of injury, etiology and interrupted stay, all of which demonstrated P values < 0.05

(except for age at injury, P = 0.06) during inter-group analysis, were included as covariates in a second set of adjusted models. Although TBI groups did not differ by age, age was included as a covariate because of its conceptual significance. Similar models were constructed for IRF LOS. Bivariate and adjusted logistic regression models were constructed to estimate associations between DD group and discharge location; home vs. institution. Sensitivity analyses were performed to assess the robustness of our findings. Specifically, associations between significantly skewed dependent variables and DD group were estimated with the nonparametric Wilcoxon rank-sum (Mann-Whitney) test, comparing the reference, "SCI Only," group to the mild and moderate-severe DD groups. Additionally, given concern that patients whose IRF stays were interrupted by transfers back to acute care differed systematically from patients whose IRF stays were not, we constructed models that included only patients with uninterrupted stays. All tests were two-tailed and an α of 0.05 was considered statistically significant. All analyses were performed using STATA v11.0 (StataCorp. 2009. *Stata Statistical Software: Release 11*. College Station, TX: StataCorp LP).

Results

Demographics

In our cohort of 256 persons with acute traumatic SCI, 59% (n = 152) had a diagnosis of SCI only and 41% (n = 104) had a DD (Mild DD, 23% and Moderate-Severe DD, 18%) (Table 2). There were no significant differences across the SCI only, Mild DD and Moderate-Severe DD groups related to sex, AIS classification or mean age. Level of injury differed significantly between the groups. Nearly the entire Mild DD group had cervical and thoracic level injuries (66.2% and 32.2% respectively) and few lumbosacral level injuries (1.7%), while the SCI only and Moderate-Severe DD groups had a larger percentage of persons with a lumbo-sacral level of injury (both 17.8%). The majority of the sample was injured secondary to a motor vehicle accident (MVA) or a fall. This demographic also differed significantly between groups, with the Moderate-Severe DD group having 84.4% of injuries secondary to a MVA while the SCI only and Mild DD groups had a lower percentage due to this mechanism of injury (37.5% and 55.9% respectively).

The onset days (acute care LOS) between accident and rehabilitation admission averaged 20 days in the total cohort. The SCI only group had the shortest mean onset days (18 days) followed by Mild DD (19 days) and Moderate-Severe DD with the longest (26 days), but did not differ significantly between the three groups. Interrupted stays (required transfer to the acute care setting for medical complications of ≥ 1 week) did differ significantly across the groups with Mild DD having the highest percentage (30.5%) followed by Moderate-Severe DD (22.2%) and SCI only

Table 2 Characteristics of the study population by TBI severity.

	ALL	SCI Only	SCI + Mild	SCI + Mod-Sev	P value
n / group	256	152 (59%)	59 (23%)	45 (18%)	
Sex (%)					0.32
Female	67 (26.2%)	43 (28.3%)	11 (18.6%)	13 (28.9%)	
Male	189 (73.8%)	109 (71.7%)	48 (81.4%)	37 (71.1%)	
Age Mean (SD)	46.4 (±20.0)	48.1 (±20.4)	45.8 (±20.8)	41.5 (±17.0)	0.06
Level of Injury (%)					0.045
Cervical	150 (58.6%)	86 (56.6%)	39 (66.1%)	25 (55.6%)	
Thoracic	70 (27.3%)	39 (25.7%)	19 (32.2%)	12 (26.7%)	
Lumbosacral	36 (14.1%)	27 (17.8%)	1 (1.7%)	8 (17.8%)	
AIS Score (%)					0.693
A	80 (31.3%)	42 (27.6%)	22 (37.3%)	16 (35.6%)	
B	20 (7.8%)	13 (8.6%)	5 (8.5%)	2 (4.4%)	
C	47 (18.4%)	31 (20.4%)	7 (11.9%)	9 (20.0%)	
D	92 (36.0%)	55 (36.2%)	22 (37.3%)	15 (33.3%)	
E	8 (3.1%)	6 (4.0%)	0 (0%)	2 (4.4%)	
N/A	9 (3.5%)	5 (3.3%)	3 (5.1%)	1 (2.2%)	
Etiology (%)					< 0.001
Fall	83 (32.4%)	60 (39.5%)	17 (28.8%)	6 (13.3%)	
MVA	128 (50.0%)	57 (37.5%)	33 (55.9%)	38 (84.4%)	
Sports	19 (7.4%)	12 (7.9%)	6 (10.2%)	1 (2.2%)	
Other	25 (9.8%)	22 (14.5%)	3 (5.1%)	0 (0%)	
N/A	1 (0.4%)	1 (0.7%)	0 (0%)	0 (0%)	

AIS, American Spinal Injury Association Impairment Scale.

having the lowest percentage of acute transfers off the rehabilitation unit (14.5%) (Table 3).

Rehabilitation LOS and discharge location outcomes

Outcome measures including rehabilitation LOS, discharge location and FIM scores were analyzed with the SCI only group as the reference group. Mean LOS for the SCI only, Mild, and Moderate-Severe DD groups were as follows: 29.4, 38.7, and 35.0 days, respectively. After adjusting for sociodemographic and clinical characteristics (age at injury, level of injury, etiology and interrupted stay), rehabilitation LOS did not differ significantly between the groups (Table 4a, Figure 1). Of note, the Mild DD group had the longest mean rehabilitation LOS (coefficient 9.26, SE 3.82, P = 0.08). The discharge location was significantly different between the SCI only group and the Moderate-Severe DD group. The odds ratio for home discharge among the Moderate-Severe DD group related to the SCI only group, in adjusted models, was 0.45, SE 0.18, P = 0.05. The odds ratio among the Mild DD group was 1.79, SE 0.71, P = 0.15 (Table 4b, Figure 2).

FIM outcomes

The adjusted models for Total FIM outcomes demonstrated that the Moderate-Severe DD group had a significantly lower Total FIM admission score, coefficient -10.51, SE 2.80, P < 0.001 compared to the SCI only. The Mild DD group did not differ significantly in any

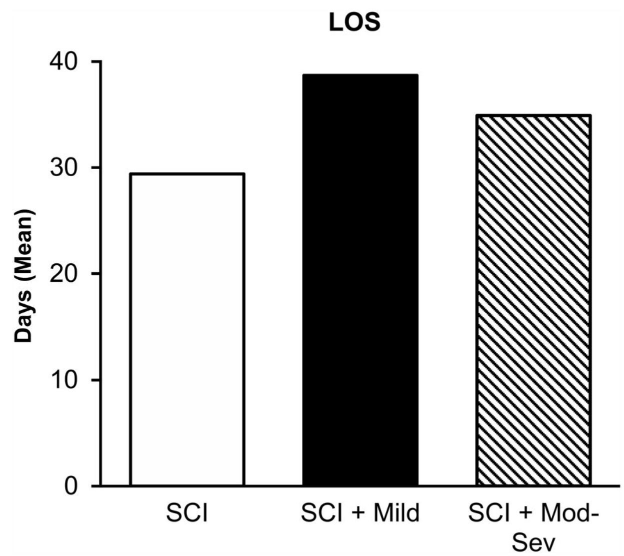

Figure 1 IRF LOS by TBI severity. Mean days were analyzed for significant differences (P ≤ 0.05) using adjusted models.

Total FIM scores compared to the SCI only group (Table 5a, Figure 3). Cognitive FIM admission scores for both Mild, coefficient -1.96, SE 0.97, P = 0.04, and Moderate-Severe, coefficient -5.97, SE 1.09, P < 0.001, DD groups were significantly lower than the SCI only group. The Moderate-Severe DD group also demonstrated significantly lower Cognitive FIM discharge scores, coefficient -3.01, SE 0.78, P < 0.001, compared to the SCI only group. There were no differences in Cognitive FIM efficiency between either of

Table 3 Hospitalization summary by TBI severity.

	All	SCI only	SCI + Mild	SCI + Mod-Sev	P value
n/ group	256	152	59	45	
Onset days					0.92
Mean (SD)	20 (±22.6)	18.4 (±23.3)	19.3 (±20.4)	26.2 (±22.5)	
Interrupted IRF Stay (%)					0.027
No	206 (80.5%)	130 (85.5%)	41 (69.5%)	35 (77.8%)	
Yes	50 (19.5%)	22 (14.5%)	18 (30.5%)	10 (22.2%)	

Interrupted IRF = transfer to acute care setting for medical complications of ≥1 week.
Onset days = acute care LOS.

Table 4a Ordinary least squares regression predicting differences in rehabilitation length of stay by TBI status.

	Rehabilitation Length of Stay					
	Model 1 (Unadjusted)			Model 2 (Adjusted)		
	b(SE)	P value	95% CI	b(SE)	P value	95% CI
TBI status						
Mild	9.26 (3.82)	0.02	(1.74, 16.79)	6.60 (3.78)	0.08	(-0.84-14.04)
Mod-Sev	5.54 (4.23)	0.19	(-2.78, 13.87)	6.23 (4.27)	0.15	(-2.18-14.64)

Note: For the focal predictor, Traumatic brain injury status, Spinal cord injury-only is the omitted reference group in all models. All beta coefficients are unstandardized. Adjusted models include age, level of injury, etiology and transfer status.

Table 4b Logistic regression estimating odds ratio of discharge to home by TBI status.

	Discharge to home					
	Model 1 (Unadjusted)			Model 2 (Adjusted)		
	Odds ratio (SE)	P value	95% CI	Odds ratio (SE)	P vlaue	95% CI
TBI status						
Mild	1.40 (0.51)	0.36	(0.69-2.84)	1.79 (0.71)	0.15	(0.82-3.91)
Mod-Sev	0.54 (0.19)	0.08	(0.27-1.08)	0.45 (0.18)	0.05	(0.20-0.99)

Note: For the focal predictor, Traumatic brain injury status, Spinal cord injury-only is the omitted reference group in all models. All beta coefficients are unstandardized. Adjusted models include age, level of injury, etiology and transfer status.

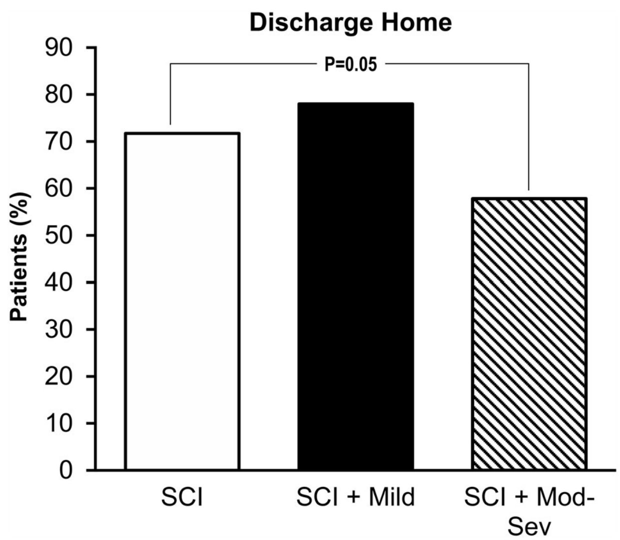

Figure 2 Discharge location by TBI severity. % patients discharging home were analyzed for significant differences (P < 0.05) using adjusted models.

the DD groups compared to the SCI only group (Table 5b, Figure 3). Motor FIM outcomes demonstrated a significantly lower Motor FIM Efficiency score in the Moderate-Severe DD group, coefficient -0.67, SE 0.30, P = 0.03, compared to the SCI only group. The Moderate-Severe DD group also had lower Motor FIM admission scores, coefficient -4.22, SE 2.20, P = 0.06, compared to the SCI only group, however no difference was noted in the Motor FIM discharge scores between these two groups. No differences were noted in any Motor FIM scores between the Mild DD group and SCI only (Table 5c, Figure 3).

Sensitivity analyses

All dependent variables except discharge Total and Motor FIM scores were significantly skewed. Results from unadjusted nonparametric tests of association between FIM scores and DD group were generally robust, although motor FIM efficiencies were not significantly different between the reference "SCI only" group and the Moderate-Severe DD group. The significance of coefficient estimates in the models that included only patients with uninterrupted IRF stays were similarly robust. Of note, the coefficient for the moderate-severe DD group's rehabilitation length of stay relative to the "SCI only" reference group was significant in

Table 5a Ordinary least squares regression predicting differences in Total FIM at Admission, at Discharge, and in Total FIM efficiency by TBI status.

Total FIM Descriptor		Total FIM					
		Model 1 (Unadjusted)			Model 2 (Adjusted)		
		Odds ratio (SE)	P value	95% CI	Odds ratio (SE)	P value	95% CI
Admission							
	TBI status						
	Mild	-4.92 (2.50)	0.05	(-9.83-0.002)	-2.60 (2.48)	0.30	(-7.48-2.29)
	Mod-Sev	-10.07 (2.76)	<0.001	(-15.51- ˉ4.62)	-10.51 (2.80)	<0.001	(-16.03- ˉ4.99)
Discharge							
	TBI status						
	Mild	-2.72 (3.82)	0.48	(-10.23-4.80)	0.56 (3.79)	0.88	(-6.91-8.03)
	Mod-Sev	-3.94 (4.22)	0.35	(-12.25-4.38)	-4.26 (4.28)	0.32	(-12.70-4.18)
Efficiency							
	TBI status						
	Mild	-0.04 (0.33)	0.89	(-0.69-0.60)	0.31 (0.34)	0.36	(-0.36-0.97)
	Mod-Sev	-0.65 (0.36)	0.08	(-1.37-0.07)	-0.56 (0.38)	0.14	(-1.31-0.19)

Note: For the focal predictor, Traumatic brain injury status, Spinal cord injury-only is the omitted reference group in all models. All beta coefficients are unstandardized. Adjusted models include age, level of injury, etiology and transfer status.

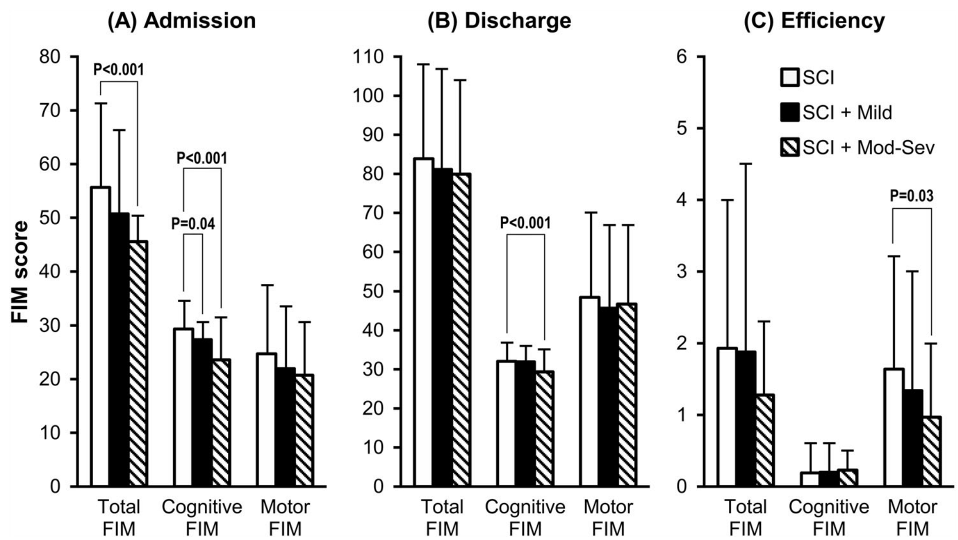

Figure 3 Comparing FIM scores by TBI severity. Total, cognitive and motor FIM (A) Admission (B) discharge and (C) efficiency scores were analyzed for significant differences (P ≤ 0.05) using adjusted models.

Table 5b Ordinary least squares regression predicting differences in Cognitive FIM at Admission, at Discharge, and in Cognitive FIM efficiency by TBI status.

Cognitive FIM Descriptor		Cognitive FIM					
		Model 1 (Unadjusted)			Model 2 (Adjusted)		
		Odds ratio (SE)	P value	95% CI	Odds ratio (SE)	P value	95% CI
Admission							
	TBI status						
	Mild	-1.99 (0.97)	0.04	(-3.89- ¯0.09)	-1.96 (0.97)	0.04	(-3.89- ¯0.05)
	Mod-Sev	-5.75 (1.07)	<0.001	(-7.85- ¯3.65)	-5.97 (1.09)	<0.001	(-8.12- ¯3.81)
Discharge							
	TBI status						
	Mild	-0.14 (0.71)	0.85	(-1.53-1.25)	-0.09 (0.69)	0.90	(-1.44-1.28)
	Mod-Sev	-2.65 (0.78)	0.001	(-4.19- ¯1.11)	-3.01 (0.78)	<0.001	(-4.55- ¯1.47)
Efficiency							
	TBI status						
	Mild	0.01 (0.06)	0.87	(-0.11-0.13)	0.03 (0.06)	0.59	(-0.09-0.16)
	Mod-Sev	0.05 (0.07)	0.47	(-0.09-0.19)	0.05 (0.07)	0.47	(-0.09-0.19

Note: For the focal predictor, Traumatic brain injury status, Spinal cord injury-only is the omitted reference group in all models. All beta coefficients are unstandardized. Adjusted models include age, level of injury, etiology and transfer status.

the sensitivity analysis, while the odds of home dismissal were not (Table 6).

Discussion

There is a paucity of recent research on the effects of TBI in persons who experience traumatic SCI, and fewer that are generated from an acute IRF within the United States. Our study provides updated information on the occurrence, severity and functional outcomes of persons with DD from this unique IRF perspective. We also are the first to report on discharge location status comparatively.

DD occurrence and severity

The occurrence of persons with DD in this study was 41%. Mild TBI comprised 57% and Moderate-Severe TBI comprised 43% of our DD sample. Compared to previous incidence studies,[8,21,22] our DD population represented a lower percentage of the total SCI (n = 256) group. For instance, Tolonen *et al.*,[21] a group whom collected data from a Finland national rehabilitation center, reported a 74% TBI incidence rate occurring in 31 persons with SCI. Dual diagnosis was determined via period of LOC, PTA, altered mental state and focal neurological findings. They found 73% of those with a DD had moderate to severe TBI, most likely due to

Table 5c Ordinary least squares regression predicting differences in Motor FIM at Admission, at Discharge, and in Motor FIM efficiency by TBI status.

Motor FIM Descriptor		Motor FIM					
		Model 1 (Unadjusted)			Model 2 (Adjusted)		
		Odds ratio (SE)	P value	95% CI	Odds ratio (SE)	P value	95% CI
Admission							
	TBI status						
	Mild	-2.78 (1.97)	0.16	(-6.64-1.10)	-0.63 (1.95)	0.75	(-4.47-3.21)
	Mod-Sev	-3.97 (2.18)	0.07	(-8.25-0.32)	-4.22 (2.20)	0.06	(-8.56-0.12)
Discharge							
	TBI status						
	Mild	-2.77 (3.24)	(0.39)	(-9.15-3.61)	0.11 (3.26)	0.97	(-6.31-6.53)
	Mod-Sev	-1.71 (3.59)	0.63	(-8.78-5.35)	-1.79 (3.68)	0.63	(-9.05-5.46)
Efficiency							
	TBI status						
	Mild	-0.29 (0.26)	0.26	(-0.80-0.21)	-0.03 (0.26)	0.91	(-0.55-0.49)
	Mod-Sev	-0.67 (0.29)	0.02	(-1.23- ¯0.11)	-0.67 (0.30	0.03	(-1.25- ¯0.08)

Note: For the focal predictor, Traumatic brain injury status, Spinal cord injury-only is the omitted reference group in all models. All beta coefficients are unstandardized. Adjusted models include age, level of injury, etiology and transfer status.

high impact mechanisms of injury such as motor vehicle crashes or falls. Macciocchi *et al.*,[8] reporting from a United States LTAC facility, found 60% of their 198 persons with SCI also had co-occurring TBI, however most persons with TBI were classified with mild injury at 75%, while the moderate to severe injury group represented 25% of the DD population. The discrepancies in total incidence across studies are multifactorial as variables such as referral patterns and rehabilitation admission criteria such as anticipated LOS differ among institutions. For example, a person with a Moderate-Severe DD may more likely be referred to an LTAC facility versus an IRF when evaluated in the acute care setting if it is anticipated that a longer rehabilitation stay will be necessary, thus creating inherent differences in both incidence and severity of TBI and DD across institutions. This demonstrates the difficulty in directly comparing outcomes across studies with differing rehabilitation settings such as LTACs vs. IRFs.

The discrepancies in reported TBI severity across institutions may also be attributed to the differences in criteria of TBI nosology, as there is no universal system used for TBI classification for retrospective or prospective studies. For instance, Macciocchi *et al.*[8] reported a 'mild complicated' TBI group which included those with PTA < 24 hours but had positive neuroimaging on CT scan. This group would have been identified as Moderate-Severe TBI in the current study using the Mayo TBI Classification system. Macciocchi's study would have then demonstrated a nearly identical percentage of mild and moderate-severe TBI in the DD group compared to our study (58% vs. 57% mild and 42% vs. 43% moderate-severe respectively). This demonstrates the need for a universal system for TBI severity classification for future studies. Future retrospectively designed studies could consider the Mayo Classification System for Traumatic Brain Injury Scale to determine TBI severity as this is an inclusive system that has shown value particularly in retrospectively designed research.[15,23–26]

Functional outcomes and LOS

Although the majority of person with DD in our sample suffered a Mild TBI, outcome measures including FIM scores and discharge location point towards the Moderate-Severe DD group as the sub-population whom may need more focused attention when admitted to an IRF.

We found the Moderate-Severe DD group had significantly lower Cognitive and Total admission and Cognitive discharge FIM scores compared to the SCI only group, however there were no significant differences in any FIM admission or discharge measures when comparing the Mild DD group to SCI only. These results are intuitive in that the presence and severity of a TBI would likely play a negative role on cognitive functional measurements when individuals are admitted to inpatient rehabilitation for SCI. Although the Moderate-Severe DD group was treated in the acute care setting for the longest period of time (longest onset days, 26.2 days vs. 18.4 days for SCI only and 19.3 days for Mild DD), acute care LOS was not significantly different when compared to the SCI only group. Therefore, those with Moderate-Severe DD likely had continued cognitive impairments related to their brain injury when

Table 6 Sensitivity analysis of FIM scores for persons with uninterrupted IRF stays.

Total FIM Descriptor		Total FIM						
		Model 1 (Unadjusted)				Model 2 (Adjusted)		
		Coefficient	% Change in coefficient	P value	Wilcoxon rank sum	Coefficient	% Change in coefficient	P value
Admission								
	TBI status							
	Mild	-3.06567	37.6%	0.33†	0.02	-1.15018	55.8%	0.70
	Mod-Sev	-11.0747	10.0%	<0.001	0.00	-12.6922	20.8%	<0.001
Discharge								
	TBI status							
	Mild	1.494559	154.9%	0.74	0.48	3.684387	>200%	0.41
	Mod-Sev	-4.14725	7.6%	0.39	0.26	-5.70611	33.9%	0.25
Efficiency								
	TBI status							
	Mild	0.297148	>200%	0.48	0.27	0.47666	53.7%	0.26
	Mod-Sev	-0.70132	15.2%	0.11	0.27	-0.749	60.3%	0.11
Cognitive FIM Descriptor		Cognitive FIM						
Admission								
	TBI status							
	Mild	-1.59944	19.6%	0.17†	0.01	-1.16768	40.4%	0.30†
	Mod-Sev	-6.23846	85.0%	<0.001	0.00	-6.42611	7.6%	<0.001
Discharge								
	TBI status							
	Mild	0.267167	>200%	0.74	0.19	0.325783	>200%	0.67
	Mod-Sev	-2.83736	7.1%	<0.001	0.00	-2.83736	74.8%	<0.001
Efficiency								
	TBI status							
	Mild	0.017223	72.2%	0.82	0.24	0.016341	45.5%	0.84
	Mod-Sev	0.034506	13.7%	0.67	0.04	0.032136	35.8%	0.71
Motor FIM Descriptor		Motor FIM						
Admission								
	TBI status							
	Mild	-1.40544	49.4%	0.57	0.16	0.000852	100.0%	1.00
	Mod-Sev	-4.41868	11.3%	0.10	0.10	-5.79905	37.4%	0.03‡
Discharge								
	TBI status							
	Mild	0.563227	120.3%	0.89	0.41	2.447609	>200%	0.53
	Mod-Sev	-1.81099	5.9%	0.66	0.59	-3.0474	70.2%	0.48
Efficiency								
	TBI status							
	Mild	-0.07966	72.5%	0.81	0.16	0.051132	>200%	0.88
	Mod-Sev	-0.72593	8.3%	0.04	0.11	-0.85202	21.2%	0.02

Continued

Table 6 *Continued.*

Total FIM Descriptor	Total FIM						
	Model 1 (Unadjusted)				Model 2 (Adjusted)		
	Coefficient	% Change in coefficient	P value	Wilcoxon rank sum	Coefficient	% Change in coefficient	P value
Rehabilitation LOS							
TBI status							
Mild	7.045028	23.9%	0.12†	0.02	5.489891	16.8%	0.21
Mod-Sev	6.751648	21.9%	0.17	0.04	9.389236	50.7%	0.05‡
Discharge Home							
TBI status							
Mild	2.081633	48.7%	0.11		2.636069	47.3%	0.06
Mod-Sev	0.642857	19.0%	0.26		0.368831	18.0%	0.06†

† P value <0.05 using total cohort (Table 5) and increased to >0.05 in sensitivity analysis.
‡ P value >0.05 using total cohort (Table 5) and decreased to <0.05 in sensitivity analysis.

admitted to inpatient SCI rehabilitation given no significant additional time was available for resolution of the TBI. Similarly, the rehabilitation LOS did not significantly differ between the Moderate-Severe DD group and the SCI only group, therefore those with Moderate-Severe DD likely had continued cognitive impairments at rehabilitation discharge as evidenced by the significantly lower discharge Cognitive FIM scores compared to the SCI only group. On the other hand, the Mild DD group did not demonstrate differences in Total or Cognitive admission or discharge FIM scores compared to the SCI only group and also did not demonstrate significant differences in acute care LOS and rehabilitation LOS compared to the SCI only group. These findings are supported by a prospective study performed to determine the impact of Mild TBI on cognitive functioning in the DD population.[27] This study found that the Mild DD sample did not have greater impairments on neuropsychologic testing compared to SCI only group at a mean of 46 days post-injury, and therefore concluded that Mild TBI in persons with traumatic SCI had negligible long-term impacts on cognition. Interestingly, our findings indicate there are no differences in Cognitive FIM efficiency among the groups, which suggests that both DD groups compared to the SCI only group made progress in cognition at similar rates of change per day.

TBI affects processing speed, problem solving, comprehension and learning. The impaired application of these cognitive skills to the initiation of learning new motor tasks may explain why persons with Moderate-Severe DD had lower admission Motor FIM scores compared to the SCI only group ($P = 0.06$). Interestingly, our Moderate-Severe DD group demonstrated no significant differences in discharge Motor FIM scores, unlike previous studies,[10] however the additional acute care plus rehabilitation days for the Moderate-Severe DD group may have allowed enough time to acquire skills that are captured by the Motor FIM scoring system at discharge similar to the SCI only group. The relatively longer rehabilitation LOS may also explain why persons with Moderate-Severe DD demonstrated significantly worse Motor FIM efficiency scores (change in FIM divided by rehabilitation LOS) ($P = 0.03$) compared to the SCI only group. These findings are important as this provides evidence that the presence and severity of TBI in persons with acute SCI affects their efficiency in obtaining motor skills during inpatient rehabilitation, which is required for successful transition to the community after rehabilitation discharge.

Discharge location

Despite similar functional motor scores on discharge, significantly fewer percentage of persons with Moderate-Severe DD (P = 0.05) discharge to their home setting compared to persons with a single SCI diagnosis. The significantly lower cognitive discharge scores may be a factor in this discharge outcome, which brings up the need for further rehabilitation efforts and longer length of stays to safely return home and reintegrate into the community. For instance, Nott *et al* [11] reported on the effects of DD vs. SCI only and TBI only regarding community reintegration several years post rehabilitation discharge. Interestingly, they found that all groups demonstrated comparable levels of participation in work, study, and volunteer activities. However, when retrospectively analyzing the characteristics of the acute care and rehabilitation course, the DD group had significantly longer acute care and rehabilitation LOSs. One of the conclusions drawn from this study was that the longer LOSs in the DD group may have provided more time for these patients to develop compensatory techniques and strategies for adaptation in the community.

Other factors may contribute to discharge disposition such as age, marital status, family support and barriers in the home setting. Previous studies looking at persons with SCI admitted to rehabilitation centers found correlations between age and discharge disposition. Older patients were more likely to be discharged to institutional settings,[28–31] however in our study the opposite was true in that the Moderate-Severe DD group had the youngest mean age of all groups, yet were significantly more likely to require ongoing care in an institutional setting vs. home. While no differences by age were observed in this investigation, prior work suggests that age is conceptually important and therefore this variable was included in all analyses. Although these other factors may play a minor role in discharge disposition, the role of memory, cognition, behavior, and new skill acquisition is most important when discharge planning as evidenced by the significantly lower Cognitive FIM discharge scores in the Moderate-Severe DD group compared to the SCI only group.

Interrupted stay

An interesting observation was demonstrated in the percentage of patients among each group transferred to the acute floor for medical complications during their rehabilitation course (interrupted stay). The SCI only group had the lowest percentage of patients requiring acute care transfer, 14.5%. However, the percentage of those with Moderate-Severe DD that transferred to the acute floor from the rehabilitation unit was 22.2%, while the percentage of Mild DD patients transferred off to the acute floor was 30.5%. These percentages seem counter-intuitive, as one would think those with less severe injuries would also experience a lower number of medical complications. One may consider the number of onset days, or days patients were stabilized on the acute floor prior to initial rehabilitation admission, as a potential factor. Although not statistically significant, the Moderate-Severe DD group had a mean of 26.2 onset days compared to the Mild DD group, 19.3 onset days. This could imply that the Moderate-Severe DD group had more time to medically stabilize on the acute floor prior to initial rehabilitation admission. There could be other measured (e.g. age) and unmeasured (e.g. infections, surgeries, etc.) variables accounting for these differences, however, sub-analysis was not completed as it was beyond the scope of this study.

Limitations

One limitation of our study is its retrospective design, in that that the initial chart review relied on documentation from acute care or inpatient rehabilitation providers of an acute TBI during the time of initial injury if neuroimaging was normal. Given our DD occurrence rate was lower than other relatively recent studies investigating dual injury, we are suspicious that TBI was under-diagnosed secondary to confounding factors such as intoxication, hypoxia, medications, etc., or under-documented during the acute care phase. Current research has shown that TBI in persons with traumatic SCI may be missed entirely.[21,22] A recent study by Sharma *et al.* [22] reported that the overall frequency of missed TBI diagnosis within their SCI cohort was 58.5% with even greater numbers shown in subjects that experienced cervical (79%) or sub-cervical (80%) injuries not related to MVAs. They concluded that acute care diagnostic protocols for TBI need further examination and that increased vigilance in persons with traumatic injuries in settings other than MVAs is necessary.

An additional limitation is the generalizability of this study. Subject charts were reviewed from a rural teaching medical center, of which our findings are only generalizable to similarly structured institutions. This was also felt to be a strength of our study due to the paucity of publications that have investigated DD in the IRF setting. Finally, the ten year time frame of initial injury can also be a limitation as spinal cord injury medicine and regulatory practice changes can influence the LOS on rehabilitation units. However, we completed a sub-analysis which demonstrated year of admission was not associated with rehabilitation LOS.

Future studies

The database created for this study could serve as a foundation for future studies that compare complications or sequel related to SCI between those with DD and SCI only, for example differences in pressure ulcer incidence, urologic management or chronic pain treatment. The goal of future studies would be to better understand both the short and long-term outcomes of persons with a dual diagnosis.

Conclusion

This study provides new information and insight into the outcome differences of persons with co-occurring brain injury as compared to those with spinal cord injury alone from an IRF perspective. We have shown that persons with Moderate-Severe DD are less efficient in obtaining motor skills during inpatient rehabilitation, have continued cognitive impairments at rehabilitation discharge and are less likely to discharge home compared to persons with a single SCI diagnosis. We speculate that the severity of cognitive impairments caused by co-occurring brain injury plays a significant role in the ability of these persons to learn and carryover new skills necessary for performing activities of daily living and self-cares in order to safely return home.

Unfortunately, the decision algorithms utilized by IRFs for determining rehabilitation LOS do not place much emphasis on cognition unless TBI is a coded diagnosis on admission. Many IRFs utilize the United Data System (UDS) to establish estimated length of stay, a calculation using the impairment group, age, and current functional status. If the TBI diagnosis is not identified for the rehabilitation LOS calculation, fewer rehabilitation days will be justified, as will reimbursement. Therefore it is imperative to identify individuals with co-occurring TBI, especially those with Moderate-Severe DD, on rehabilitation admission to justify longer rehabilitation LOS to accomplish similar tasks of those with a single SCI diagnosis.

Knowledge of the effects of co-occurring TBI in spinal cord injured persons can assist providers in customizing a comprehensive rehabilitation program to target both the skills specific for spinal cord injury, and the cognitive skills vital for processing and retaining the new information. This study and others further supports the need to identify and separate the dual diagnosis population from the standard practice involving the care for persons with spinal cord injury. The goal is to ensure necessary increases in LOS and to redefine the comprehensive rehabilitation program, with the long term effect of improving lifelong outcomes of this population.

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